Bee exposure to foliar insecticides and fungicides in pumpkin pollen and nectar depends on chemical and time since spray

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Risk of bee exposure to foliar sprays

- Crop protective products used as foliar sprays are often applied when flowers are absent or closed to minimize exposure to pollinators (1, 2).
- We poorly understand translocation and persistence of foliar-applied chemicals into nectar and pollen, or whether freshly sprayed foliage may harm pollinators via physical contact.
- We assess the frequency and persistence of foliar-applied insecticides and fungicides in the pollen, nectar, and leaves of pumpkin, a pollinator-dependent plant with short-lived flowers.

Research Questions

- **With what frequency are foliar insecticide and fungicide residues found in pumpkin pollen, nectar, and leaves?**
- **Does time since spray influence detection of residues?**
- **Are insecticides and fungicides detected in bees visiting pumpkin flowers?**

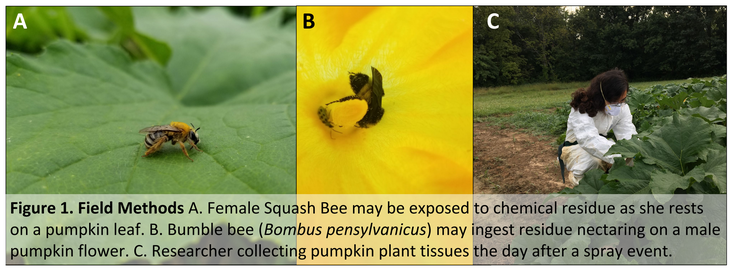

Figure 1. Field Methods A. Female Squash Bee may be exposed to chemical residue as she rests on a pumpkin leaf. B. Bumble bee (*Bombus pensylvanicus*) may ingest residue nectaring on a male pumpkin flower. C. Researcher collecting pumpkin plant tissues the day after a spray event.

Field and lab methods

- Visited five farms in central Ohio 1d before, 1d, 3d, and 7d after foliar spray events (Fig 1).
- We collected pollen (+ synandrium) and nectar from ~40 male flowers and 20 leaves.
- We collected up to 10 of each type of bee foraging on pumpkin flowers 1d before and 1d after spray events: bumble bee workers (*Bombus* spp.), honey bee workers (*Apis mellifera*), and squash bee males and females (*Eucera pruinosa*).
- Pesticide residue analysis was conducted on 1g of leaf, pollen + synandrium tissue, and nectar (SGS, Brookings, SD).
- 1-5 bees of the same species were combined to make 1g samples for residue analysis.
- Hazard quotients: HQ = [max value in tissue (PPB) / LD_{50} (ug/bee)] (3)

Tissue HQ > 50 high – exposure or consumption of 0.05% LD_{50}/d
Tissue HQ > 500 very high – exposure or consumption of 0.5% LD_{50}/d

Chemicals sprayed

Table 1. Plant Protective Products Sprayed on Pumpkins. Limit of quantification (LOQ) for residue analyses, LD_{50} for honey bees represented as (ug/bee) (3 for Sevin contact acute LD_{50}, otherwise, 4).

Commercial Name	Class	Chemical Residue Tested	LOQ (ug/kg)	Contact Acute LD_{50}	Oral Acute LD_{50}
Sevin	insecticide	Carbaryl[1]	10	1.1	>0.21
Perm-Up	insecticide	Permethrin, cis & trans[2]	10	0.02	0.13
Lambda Cyhalothrin	insecticide	Cyhalothrin, total[2]	20	NA	0.03
Bravo	fungicide	Chlorothalonil[3]	10	> 101.00	> 63.00
Procure	fungicide	Triflumizole[4]	20	20.00	14.00
Quintec	fungicide	Quinoxyfen[5]	NA	>100.00	>100.00

Chemical classes 1. Carbamate, 2. Pyrethroid, 3. Organochlorine, 4. Imidazole, 5. Quinoline.

Results: Detection frequency and timing

Insecticides

- All insecticides sprayed (Table 1) were detected in leaves at high frequency; many exceeded relevant honey bee LD_{50} (Fig 2)
- 30% of pollen, 43% of nectar, and less than 2% of bees had Sevin residues (Fig 2).
- Sevin maximum HQ >>50 for all tissues (Fig 2).
- Perm-up detected in 50% of samples with maximum HQ_{Leaf} >> 500 1d and HQ_{Pollen}> 50 7d after spray (Fig.2).
- Lambda cyhalothrin detected in 100% of leaf samples 3d and 7d after a spray, not in nectar or pollen.

Fungicides

- Procure residues detected high HQ_{Leaf} through 7d; also found in 50% of pollen samples, but at low HQ (Fig 3).
- Quintec residues translocate into pollen, where they reached very high maximum HQ before and after sprays (Fig 3).

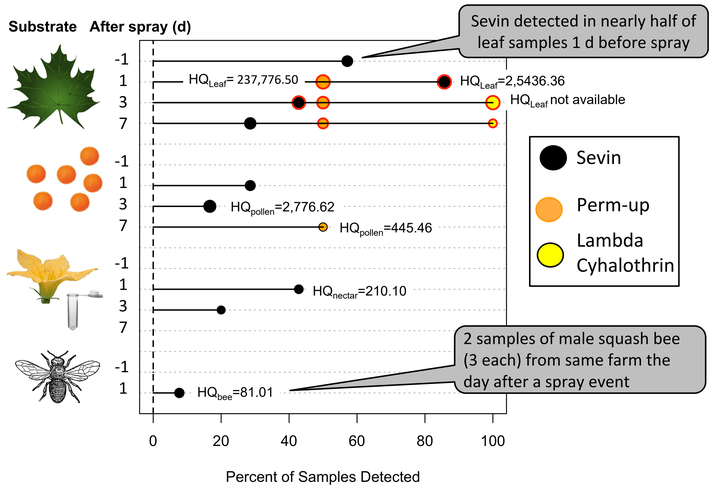

Figure 2. Insecticide Detection Frequency. Percent of samples in which insecticides sprayed were detected shown for substrates (leaf, pollen + synandrium, nectar, and bees) and days since spray. Dot size represents rank of maximum values within insecticides. Red borders indicate maximum value exceeded the contact acute (leaf and bee) or acute oral (pollen and nectar) LD_{50} for honey bees. Hazard Quotients (HQ_{tissue}) represent maximum for each tissue-insecticide combination.

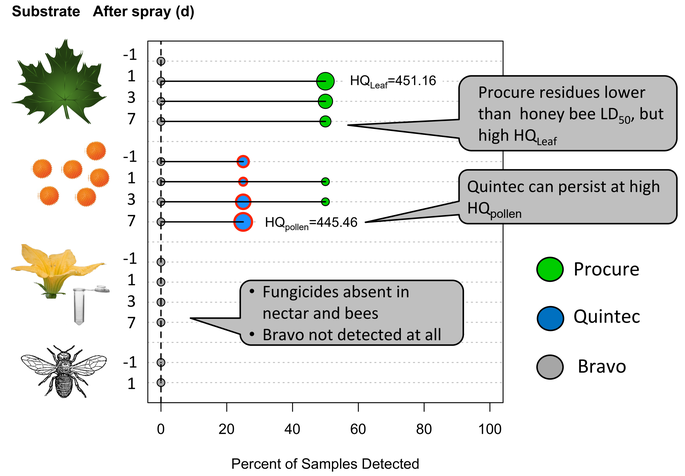

Figure 3. Fungicide Detection Frequency. Percent of samples by time since spray and sample type in which each sprayed fungicide was detected. Dot size is scaled within fungicides by rank of the maximum value detected. Red outline and HQ as in Figure 2. Procure not tested in bees.

Discussion

- **Grower-applied foliar sprayed insecticide residues found at high HQ cause lasting risk to bees contacting leaves.**
- **Translocation of Sevin at high HQ to pollen and nectar exposes adult and larval bees**. Research on health effects at adult and larval stages needed.
- Insecticides rarely found in bee samples, but chance of detecting high concentrations is low, and we did not test larvae, the primary consumers of pollen.
- **Fungicide Quintec, frequently found in pollen, contaminates the primary protein source for specialist Squash Bees**. Research on its effects on larval bees and their gut microbial community is needed.
- **Spraying pumpkin when flowers are closed does not protect pollinators from exposure to harmful chemicals at HQ orders of magnitude higher than maximum acceptable levels.**

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